



Earth Science Enterprise Technology Planning Workshop

Large, Lightweight Deployable Antennas

**Dan Schaubert (U Mass), Co-Chair
Ramesh Kakar, NASA HQ , Co-Chair
Michael Lou (JPL), Facilitator**

23-24 January 2001



Earth Science Enterprise Technology Planning Workshop

Large, Lightweight Deployable Antennas

Agenda

Tuesday, JAN 23, 2001

Presenter

- Chris Ruf - Mich
- Tom Jackson - USDA
- Paul Rosen - JPL
- Cal Swift - UMass
- Dara Entekhabi - MIT
- Yahya Rahmat-Samii - UCLA
- Wendy Edelstein - JPL
- Bob Bokulic - APL
- Michael Brown - NRL
- Micheal Tupper - CTD, Inc.
- Cliff Willey - JHU/APL

Topic

- “Large Radiometer Arrays in Space: Science and Technology Issues”
- “Soil Moisture Remote Sensing”
- “Antennas for NASA Earth Science Radar Missions”
- “Review of Requirement for Remote Sensing of Ocean Salinity”
- “Large Light weight Deployable Antennas”
- “Large Antennas in Space-Concepts, Options, and Challenges”
- “Inflatable Membrane Radar Antennas for Earth Science Applications”
- “Problems and Solutions Associated with Inflatable Communications Antennas”
- “Design of a Continuous Longeron Truss Boom Called Superstring”
- “Elastic Memory Composite (EMC) Materials for Deployable Antenna Structures”
- “Inflatable Communication Antenna Technology”



Breakout Session Attendees

Anders, Roland	Northrop
Bekey, Ivan	Bekey Designs
Bobcyk, Wayne	Ball
Brown, Mike	NRL
Bukulic, Bob	APL
Chase, Peter	TRW/Astro
Cosmo, Mario	SAO
Cravey, Robin	NASA/LaRC
Dobson, Craig	U Mich
Doiran, Terence	NASA/GSFC
Edelstein, Wendy	JPL
Entekhabi, Dara	MIT
Farley, Rodger	NASA/GSFC
Fujita, Tosh	JPL
Garza, Mario	Orbital
Gierow, Paul	SRS Tech
Grahne, Mark	ILC Dover
Higashi, Bob	Honeywell
Im, Eastwood	JPL
Jackson, Tom	USDA
Kajii, Makoto	NASDA
Kakar, Ramesh	NASA HQ

Lou, Michael	- JPL
Marks, Geoff	- TRW/Astro
Neeck, Steve	- NASA/GSFC
Njoku, Eni	- JPL
Ramat-Samii, Yahya	- UCLA
Reed, Bill	- TRW
Roler, Max	- Sverdrup
Rosen, Paul	- JPL
Ruebsamen, Dale	- Honeywell
Ruf, Chris	- U Mich
Schaubert, Dan	- U Mass
Schulze, Ron	- JHU/APL
Showen, Robert	- Raytheon/Ames
Swift, Cal	- U Mass
Talley, Michael	- NASA/LaRC
Tupper, Michael	- CTD
Walter, Steven	- Aerojet
Willey, Cliff	- JHU/APL
Williams, Liz	- NASA HQ
Woods-Vedeler, Jessica	- NASA/LaRC
Yueh, Simon	- JPL



Requirements for Large, Lightweight Deployable Antennas: Planar Arrays

Science / Measurement

- Soil Moisture Radiometer
 - 10 km horizontal resolution
 - 1 to 3 day revisit time
- GEO Atmospheric Sounder
 - 60 GHz Temperature Channel
 - 183 GHz Water Vapor Channel
 - 50 km horizontal resolution
- Topography/Hazards SAR
 - 10-30 m horizontal resolution
 - 8 day revisit time
- Biomass/Freeze/Thaw SAR
 - 0.1 to 1 km horizontal resolution
- Precipitation Radiometer
 - 3 hour revisit time
 - Constellation
- Subsurface Probing
 - 50-200 MHz

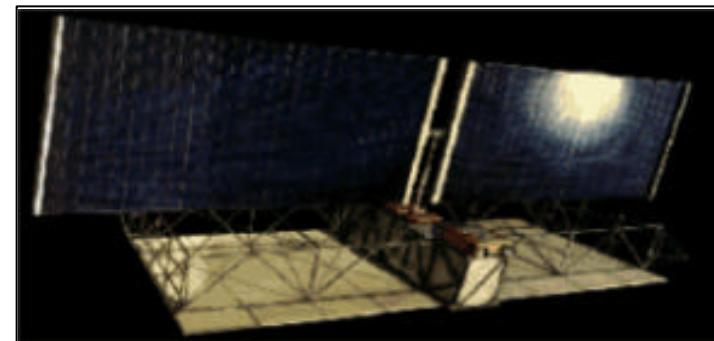
Missions Enabled/Enhanced

- Soil Moisture Mission
- GEO Sounder Mission
- Hazards Mission
- Freeze/Thaw Mission

Description of Technology

- Soil Moisture Radiometer
 - 20 x 20 m flat panel array antenna
- GEO Atmospheric Sounder
 - 5 x 5 m flat panel array antenna
- Topography/Hazards SAR
 - 3 x 10 m flat panel array antenna
- Biomass/Freeze/Thaw SAR
 - 3 x 10 m flat panel array antenna
- Precipitation Radiometer
 - 3 x 3 m flat panel array antenna

Illustration of Technology





State of the Art for Large, Lightweight Deployable Antennas: Planar Arrays

State of the Art for the Technology

- 10 x 3 m mechanically-deployed SAR Antenna (TRL9 - STRM)
- Inflatable Deployable SAR Antenna
 - Lab Demo (TRL4)
 - 3x1 m Inflatable Array
 - 0.5 to 1 mm flatness
 - Engineering Model (TRL 3)
 - 3 x 5 m Single-Wing Inflatable Array

Illustration of State of the Art

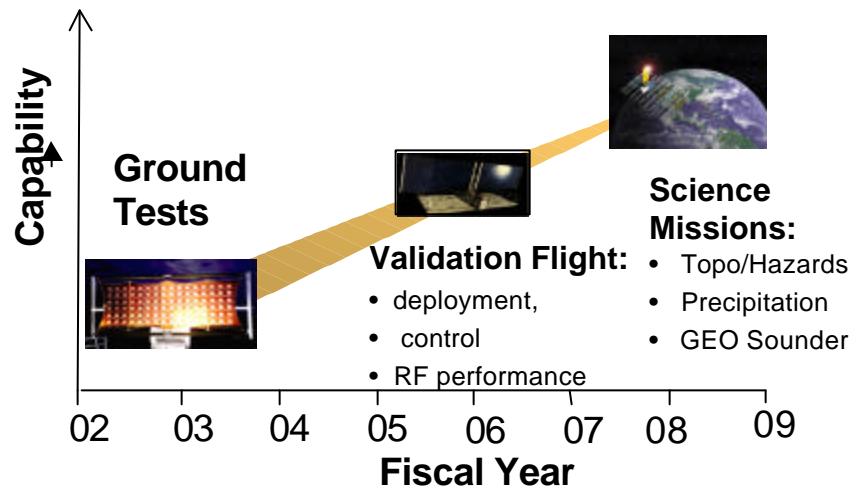


3.3m x 1m L-band
Inflatable SAR radar array

Major Technology Elements and TRL

- Lightweight Space Deployable Structure
 - NGST sun shade (TRL 3 - 4)
 - active control of structure (TRL 4)
- Membrane
 - surface profile (TRL 4 for 1 x 3 m)
 - surface roughness (TRL 3)
 - material survivability (TRL 4)
 - handling, packaging, thermal control (TRL 3)
 - alternate materials (TRL 3-4)
- Focal Plane Compensating Arrays (TRL 3)
 - beam efficiency
 - polarization

Technology Roadmap





Requirements for Large, Lightweight Deployable Antennas: Reflector Antennas

Science / Measurement

- LEO Rain Radar
- Soil Moisture Radiometer
- GEO Rain Radar
- Ocean Salinity
- Ocean Surface Wind Vector

Missions Enabled/Enhanced

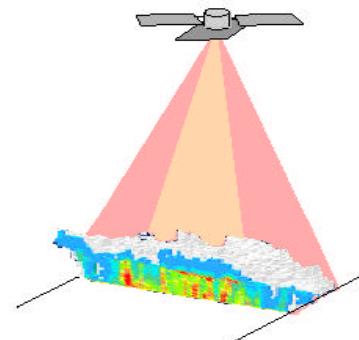
- Soil Moisture Mission
- Hazards Mission
- GPM Follow-on
- Ocean Salinity

Description of Technology

Inflatable, rigidizable or mechanical structure with surface mesh or membrane

- Spin Scanned Reflector
- Spin-Scanned Feed
- Push-Broom

Illustration of Technology



Rain Radar based on a 5 x 5 m cylindrical push-broom antenna



State of the Art for Large, Lightweight Deployable Antennas: Reflector Antennas

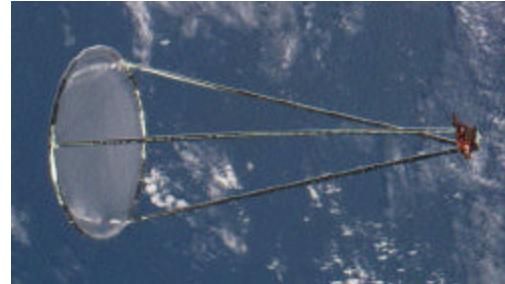
State of the Art for the Technology

- Inflatable Deployable Dish Antenna
 - STS-77 Spartan Inflatable Dish Antenna Demo (TRL 5)
 - Inadequate surface smoothness
 - No demonstration of rigidization
 - Attainment of design shape in space
- TRW Large Mesh Antenna
 - Space qualified 12.5m @ L-band
 - Extendable in size and frequency
 - Microwave emissivity requires evaluation

Major Technology Elements and TRL

- Lightweight Space Deployable Structures
 - Mechanically deployable structures (TRL > 4)
 - Inflatable structures (TRL 2-4)
 - Active control of structure (TRL 2)
- Membrane
 - Surface profile (TRL 4 for 1 x 3 m)
 - Surface roughness (TRL 3)
 - Material survivability (TRL 4)
 - Handling, packaging, thermal control (TRL 3)
 - Microwave emissivity requires evaluation
- Subreflector and focal plane compensation methods
- Shape and RF metrology

Illustration of State of the Art



Inflatable Antenna Experiment

- Uncontrolled deployment
- Space validation of surface accuracy not achieved

Technology Roadmap

Ground Tests



Validation Flight:
• rigidization
• control/ monitoring

Fiscal Year



Science Missions:

- Sea Surface Salinity and temperature
- Soil Moisture



Science and Technology Drivers for Large, Lightweight Deployable Antennas

Science Element	Driving Requirements						
	Freq.	Size	Pol	Swatch	q_i	Other	
Precipitation	≥ 10	$\geq 3m$	Dual Lin.	$\pm 50^\circ$	Const.	<ul style="list-style-type: none">• Multiple frequencies• Pointing accuracy• Active and passive	<p style="text-align: center;">↑ Better Spatial Resolution And More Frequent Revisits</p> <p style="text-align: center;">↓</p>
Soil Moisture	1.4	25m	Dual Lin.	$\pm 50^\circ$	---	<ul style="list-style-type: none">• Beam Efficiency >95%• Low loss < 0.3dB• Pointing Accuracy	
Ocean Salinity	1.4	6/25m	Dual Lin.	$\pm 50^\circ$	Const.	<ul style="list-style-type: none">• Beam Efficiency > 97% (Earth <1%; Sky < 3%)• Low loss < 0.3dB• Pointing Accuracy	
Interferometric SAR	1.2	50m GEO	Dual Lin.	Full Disk		<ul style="list-style-type: none">• High Power• Pointing Accuracy	
Ocean Surface Wind Vector	13	6m	Dual Lin.	$\pm 65^\circ$	---	<ul style="list-style-type: none">• Cross-pol < -35dB• Pointing Accuracy	
Microwave Sounder	> 50	6m	Lin.	Full Disk		<ul style="list-style-type: none">• Pointing Accuracy	
SubSurface SAR	0.05-0.20	>25m	Dual Lin.	---	---	<ul style="list-style-type: none">• High Power	
Precipitation Radar (LEO)	14/35	6m	Dual Lin.	$\pm 37^\circ$	---	<ul style="list-style-type: none">• Match-beam at 2 frequencies	
Hurricane Monitoring Radar (GEO)	35	25m	Dual Lin.	8° Full Disk		<ul style="list-style-type: none">• Sidelobe < 30 dB• Cross-pol < 25 dB	
Communications	≥ 10	3m	CP	---	---	<ul style="list-style-type: none">• Pointing Accuracy	



Validation of Large, Lightweight Deployable Antennas: Planar Arrays

Description/Justification of Proposed Space Validation

- Deployment, rigidization, control and monitoring of large deployable structure
 - Validate rigidization, gas release
 - Structural accuracy and stability
 - Characterize vibration/ thermal shock
 - Validate material characterization and survivability
- RF performance
 - Validate loss, cross-pol isolation, calibration for radars
 - Validate loss, cross-pol isolation, beam efficiency and calibration for radiometers

Accommodation Requirements

- 3 x 10 m test antenna
 - Mass 150 kg (50 kg for antenna alone)
 - Volume 3.5 by 0.5 by 1 m
 - Power
 - Deployment (TBD)
 - Operations (SAR - 500 Watts; Radiometer - 50 Watts)
 - Data Rate (TBD)
- Shuttle, free flyer, or space station (TBD)

Expected Benefits

- Flight needed to validate structure/thermal design tools
- Validate deployment, rigidization, and on orbit control needed to mitigate risks
- Validate RF performance
- Validate radiometer calibration

Top-Level Development and Flight Schedule

- L-band ready for flight
 - Phase A FY01
 - Phase B FY 02
 - Validation Flight FY 2005-2006
- Science mission implementation
 - As early as FY 2008





Validation of Large, Lightweight Deployable Antennas: Reflector Antennas

Description/Justification of Proposed Space Validation

- Deployment, rigidization, control and monitoring of large deployable structure
 - Demonstrate rigidization, gas release
 - Structural accuracy and stability
 - Characterize vibration/ thermal shock
 - Demonstrate material characterization and survivability
- Pointing
 - Rotating antenna
 - Rotating feed horn
- Figure Variation vs Radius
- Radiometric performance
- Effects of outgassing and thermal loads on pointing stability
- Active Control of optics and structures

Accommodation Requirements

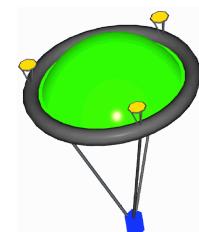
- Mass 150 kg
- Small stowed volume
- Surface and antenna-pattern metrology (TBD)
- Power (TBD)
 - Deployment
 - Radar
 - Radiometer

Expected Benefits

- Flight needed to validate structural/thermal performance
- Validate lightweight deployment (and rigidization)
- Validate radiometer quality (Beam efficiency, cross-polarization isolation and surface reflectivity/emissivity)
- Demonstrate on-orbit control of large, rotating space structure

Top-Level Development and Flight Schedule

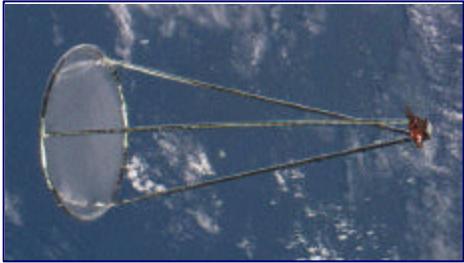
- 10 m class antennas ready for flight validation
 - Phase A: FY 02
 - Phase B FY 03
 - Validation Flight FY 2005-2006
- Science mission implementation
 - As early as FY 2008





Large Deployable Antennas Benefit Multiple Earth Science Applications

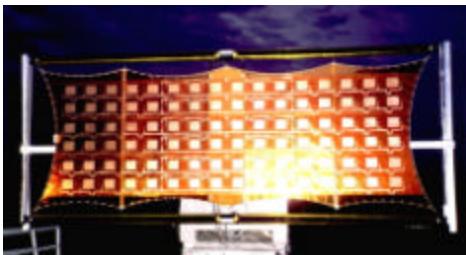
Inflatable Deployable Antenna



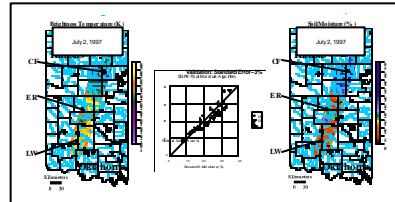
Large Deployable Mesh Antenna



Planar Array Antenna

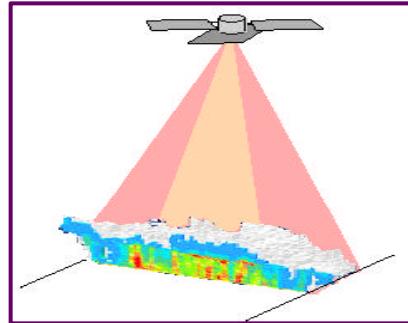


Soil Moisture Measurements



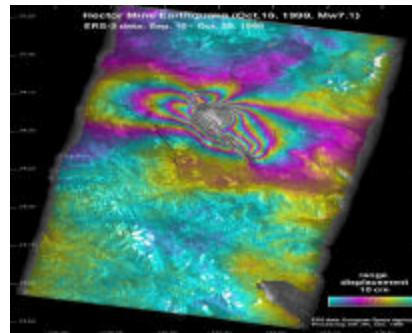
- 25m class antennas for 10km horizontal resolution

Global Precipitation/Salinity/Ocean Wind Vector Measurements



- 5-20m class antenna for 2km horizontal resolution with wide-swath scan
- Potential extension to geostationary orbits
- Potential extension to LEO constellations

Natural Hazard



- 3x10m antennas for wide-swath/high SNR
- Potential extension to geostationary orbits
- Potential extension to LEO constellations

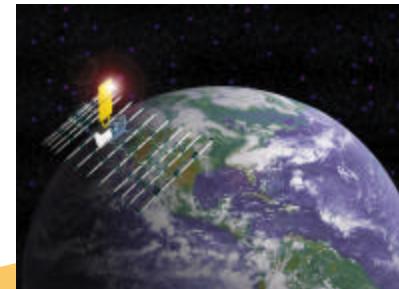


Roadmap for Large, Lightweight Deployable Planar Arrays

Requirements:

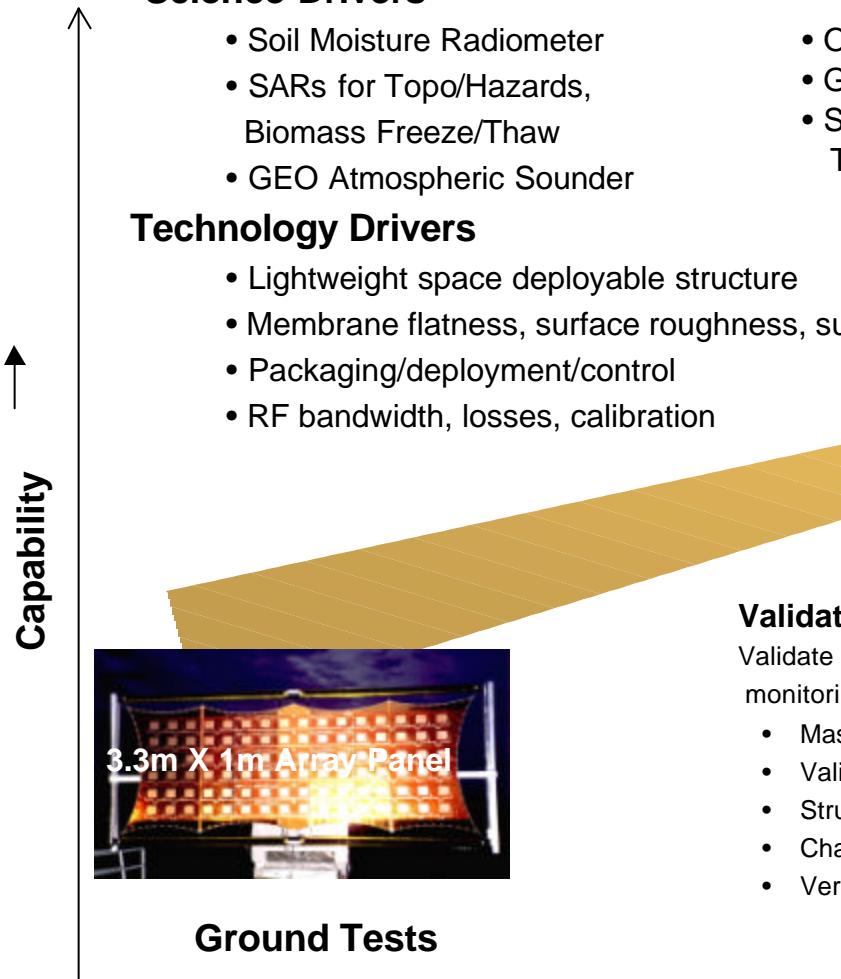
• Science Drivers

- Soil Moisture Radiometer
- SARs for Topo/Hazards, Biomass Freeze/Thaw
- GEO Atmospheric Sounder
- Ocean Surface Winds
- Global Precipitation
- Sea Surface Salinity and Temperature



Technology Drivers

- Lightweight space deployable structure
- Membrane flatness, surface roughness, survivability,
- Packaging/deployment/control
- RF bandwidth, losses, calibration



Ground Tests

Validation Flight:

Validate deployment, rigidization, control and monitoring of 3x10m inflatable antenna

- Mass 50kg for antenna
- Validate deployment, rigidization, space survivability
- Structural accuracy/stability for 1 to >10 GHz
- Characterize vibration/thermal behavior
- Verify performance for radiometer

Science Missions:

(with large deployable planar array antenna)

- Topo/Hazards
- Precipitation
- GEO Sounder



Roadmap for Large, Lightweight Deployable Reflector Arrays

Requirements:

- **Science Drivers**
 - Soil Moisture and Ocean Salinity Radiometers
 - Rain Radars
 - Ocean Surface Wind Vector
- **Technology Drivers**
 - Lightweight space deployable structures
 - Membrane shape, surface roughness, survivability, packaging/deployment/control

↑
Capability



Ground Tests



Validation Flight:

Demonstrate rigidization, control and monitoring of large inflatable antenna

- 25m diameter class antenna, 150 kg
- Shape control of antenna surface
- Measuring shape and smoothness for 1 to 100GHz
- Control of flexible structure dynamics
- Pointing accuracy/control
- Effects of out-gassing/thermal loads



Science Missions:

(with 20-25 m class deployable reflector)

- Sea Surface Salinity and temperature
- Soil Moisture

02

03

04

05

06

07

08

09

Fiscal Year